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(54) **Synchronous electric motor, particularly for submersible pumps, and pump including the motor**

Synchronmotor besonders für Tauchpumpen und elektrische Motorpumpen

Moteur synchrone électrique surtout pour pompes à moteur submersible et pour moto-pompes électriques

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## Description

The present invention relates to a synchronous electric motor, particularly but not exclusively for submersible pumps, including a stator lamination pack provided with at least one electric winding and a rotor made of a material with high magnetic retentivity.

The invention equally relates to a modular stator capsule particularly for electric motors of the above described type, and to a series of submersible pumps actuated by these motors.

In particular, submersible pumps according to the invention can be applied in several industrial and household applications, for example for recirculating the water in aquariums or ornamental tanks or for pumping dangerous liquids contained in cans, drums or tanks in general.

As is known, all synchronous electric motors have the property of maintaining a constant speed if the applied loads vary, and small motors are characterized by a low manufacturing cost.

Constructively, they include a fixed part, or stator, that supports the electric windings, and a rotor provided with permanent magnets.

The stator is formed by a pack of laminations made of ferromagnetic material which are generally C-shaped with parallel segments provided with electric windings for generating the magnetic field. The rotor is arranged between the parallel segments, and its rotation axis is at right angles to the plane of arrangement of the laminations of the pack (see for example US-A-3,390,289).

Due to this configuration, devices actuated by these motors have considerable dimensions in at least two mutually perpendicular directions. This is due to the right-angled arrangement of the rotor axis and of the axis of the stator coils, and also to the fact that, in most cases, the rotor axis is parallel to, or coincides with, the main axis of the device.

In particular, submersible pumps driven by such a motor have substantially identical dimensions in three mutually perpendicular directions, because it is never possible to significantly reduce one of these dimensions.

Consequently, these pumps are difficult to insert in containers which have openings with a small diameter. Their shape is also difficult to conceal, and this is an important drawback for certain applications, such as, for example, in ornamental aquariums or fountains for apartments.

From US-A- 4,684,840 a synchronous electric motor is disclosed in accordance with the preamble of claim 1. However, the free ends of the segments of the U-shaped stator does not enclose the rotor. This latter is housed in a detachable driving unit encapsulating shoe-members having laminations extending radially of the rotor axis, thus increasing the transverse dimensions of the motor.

It is known that synchronous electric motors have

difficulty in starting due to the symmetry of the magnetic field generated by the stator and by the rotor.

In order to avoid this problem, the stator is configured so as to have asymmetries of its magnetic field that avoid magnetic "stickings" during startup.

Motors meant to be used in submersible pumps must be protected by a double insulation, usually provided by resin-embedding the electric parts, which is not always satisfactory.

A further limitation of known commercially available pumps can be constituted by their poor flexibility and by the lack of modularity of their components, including the electrical ones, and this factor considerably increases production costs and, subsequently, maintenance costs.

The aim of the present invention is to eliminate the drawbacks described above by providing a synchronous electric motor having a predominantly axial extension, such as to considerably reduce space occupation in a transverse direction.

An object is to provide a modular stator assembly for the manufacture of synchronous motors of absolute reliability and insulation.

A further object is to provide submersible pumps having a predominantly axial extension with various configurations, characterized by extreme flexibility, easy assembly and economy.

This aim and these objects are achieved, according to the invention, by a synchronous electric motor as claimed in the appended claims.

The lamination pack is generally U-shaped with substantially straight and parallel segments. On at least one segment the lamination pack has an electric winding in which the turn axis is substantially parallel to the rotor axis.

The laminations of the stator pack also have, along the parallel segments, widths which differ continuously or discontinuously along a transverse direction with respect to the rotor axis to substantially follow the curvature of the rotor.

Along the internal profile of the parallel segments, the laminations of the pack have a recess suitable to locally reduce the axial component of the magnetic flux.

Conveniently, the stator lamination pack, together with its windings, is fully embedded in a block of insulating resin which is in turn enclosed tight within a substantially rigid container made of dielectric material, so as to form a modular and interchangeable capsule.

At an axial end, this container has a cylindrical recess that extends between the parallel segments of the pack and is sized so as to accommodate the rotor. At the opposite end, the container has a substantially flat wall.

According to a further aspect of the invention, a submersible pump is provided particularly for aquariums. The pump is driven by a synchronous electric motor of the above described type and is characterized in that it includes a modular stator capsule which can be coupled

to interchangeable rotor units having different configurations.

Further characteristics and advantages of the invention will become apparent from the detailed description of some preferred but not exclusive embodiments of the motor and of the submersible pump according to the invention, illustrated with the aid of the accompanying drawings, wherein:

Figure 1 is a partially sectional side view of a motor and of a stator capsule according to the invention; Figures 2a and 2b are front sectional views, taken along the plane II-II, of the motor of Figure 1 in two alternative embodiments;

Figure 3 is a longitudinal sectional view of the motor of Figure 1, taken along the plane III-III;

Figure 4 is a partially sectional side view of a stator capsule which encloses the stator assembly of Figure 1;

Figure 5 is a general perspective view of the stator capsule of Figure 4;

Figure 6 is a general exploded perspective view of a first embodiment of a submersible pump according to the invention which uses the stator capsule illustrated in Figure 5;

Figure 7 is a longitudinal sectional view of the pump of Figure 6;

Figures 8 and 9 are sectional views of two alternative embodiments of pumps according to the invention which use the stator capsule of Figure 5.

With reference to the figures, a synchronous electric motor particularly suitable for operations of submersible pumps is generally designated by the reference numeral 1. Three mutually perpendicular main axes X, Y and Z have been indicated in this motor.

The motor includes a stator assembly 2 and a rotor 3. The stator assembly includes a pack of laminations 4, made of ferromagnetic material which are contained in planes which are parallel to the main plane X-Z, and are substantially U-shaped so as to form parallel segments 5, 5'. Respective electric coils 6, 6' are wound on these segments; the axes A, A' of their turns are substantially parallel to the main axis Z, and the coils have electric terminals 7, 7'.

The ends of the segments that protrude from the coils 6, 6' form the stator poles.

Along the parallel segments 5, 5', the widths of the laminations of the pack in the direction of the axis X vary in the direction of the axis Y, so as to produce polar asymmetries in the magnetic flux which are suitable to stop the rotor in preferential positions which are spaced from the magnetic axis and avoid "magnetic sticking" during startup. These steps furthermore substantially follow the curvature of the rotor 3 to contain losses in the air gap, improving the efficiency of the motor.

In particular, the laminations 4 are wider toward the lateral regions of the pack which are furthest from the

axis Z in the direction of the axis Y, so as to form longitudinal steps on the segments 5, 5'. In the embodiment of Figure 2a there is only one step 8a on each side, whereas two steps 8b on each side are formed in the embodiment of Figure 2b.

Along the internal profile of the parallel segments and proximate to the coils 6, 6', the laminations 4 also have a recess 9 which has the purpose of creating a pinch in the magnetic flux meant to reduce the axial component of this flux, increasing the radial one.

At the free ends of the segments 5, 5', the laminations 4 can have chamfers 10 which are arranged at approximately 45° with respect to the axis Z and are suitable to reduce the dimensions of the stator assembly for particular applications which will be described hereinafter.

It is noted that the arrangement of the rotor 3, so that its axis is parallel to the main dimension of the stator assembly, allows to increase the length L of the rotor without increasing the longitudinal dimension of the assembly and fully exploits the intensity of the magnetic flux of the stator.

In this manner it is possible to provide synchronous motors which, power for power, have smaller transverse dimensions, have smaller rotors or electric coils with a smaller number of turns or with a wire of larger diameter than conventional motors. It is thus possible to obtain considerable economic advantages, considering that larger diameter enameled electrolytic copper wire has a lower specific cost.

Conveniently, the stator assembly 2 is sealed tight within a container 11 made of a substantially rigid dielectric material, where it is embedded within a matrix of insulating resin 12 so as to form a stator capsule 13.

The container 11 generally has a cylindrical shape with internal dimensions that substantially follow the outer profile of the stator assembly, so as to minimize the amount of insulating resin and consequently the weight and cost of the motor. The end wall 14 of the container is substantially flat and can have electric connectors 15 for supplying power to the motor, whereas the opposite wall 16 has a cylindrical seat 17 meant to accommodate the rotor 3.

A sealed switch 19 can be provided on the side wall 18 of the container 11.

The stator capsule 13 constitutes a modular basic component for producing double-insulated synchronous electric motors. The capsule may be rigidly coupled, in a per se known manner, to different rotor units, designated by the reference numeral 20 in Figures 6, 7 and 8 and described in detail hereinafter, so as to produce various models of submersible pump P.

With reference to Figures 6 and 7, the rotor unit 20 can be formed by an outer shell 21 which has a generally cylindrical shape with an open end 22 for the close-fit insertion of the stator capsule 13. Inside the shell 21 there is a pressure chamber 23 which is connected to an intake grille 24 and to a delivery duct 25. The pres-

sure chamber 23 accommodates an impeller 26 which is keyed on the axis 27 of the rotor 3. In this embodiment, the delivery duct 25 is parallel to the longitudinal axis Z of the pump and is directed opposite to the end wall 28 of the shell 21, forming as a whole a pump model which can be defined as an "axial reversed flow" pump.

The embodiment of Figure 8 differs from the one shown in Figures 6 and 7 in that the delivery duct 25' is always axial but is directed toward the end wall 28', forming a pump model which can be defined as an "axial direct flow" pump.

Finally, in the embodiment illustrated in Figure 9 there is a radial delivery duct 25" with an axial intake 29, forming a "radial flow" model.

Independently of the particular configuration of the above described pumps, it is evident that the arrangement and coaxial coupling of the rotor unit 20 to the motor 1, and thus also to the stator capsule 13, reduces the size of the pump, which extends predominantly in the direction of the axis Z, with reduced transverse dimensions along the axes X and Y.

This configuration allows to insert the pump 2 in containers provided with small inlet openings, such as for example cans containing dangerous fluids.

A series of submersible pumps driven by coaxial motors according to the invention, particularly suitable for different uses, is manufactured very quickly and according to the indications of the customer by easily assembling the prefabricated modules which include the motor, the stator capsule and the rotor units.

This is a considerable saving for production, and allows considerable flexibility which adapts well to the requirements of the market.

Experimental tests have also shown that the particular arrangement of the rotor coaxially to the stator coils improves the efficiency of the motor and pickup during startup.

By coupling the motor coaxially to a submersible pump it is possible to considerably reduce the transverse size of the pump, allowing to insert it in small-diameter openings or to easily conceal it if there are aesthetic reasons.

A stator capsule according to the invention constitutes a basic module which can be easily applied to different devices, driven by an axially extending synchronous motor according to the invention, allowing extreme flexibility in use and economy in the manufacture of these devices.

## Claims

1. A synchronous electric motor, particularly for submersible pumps, comprising:

a stator lamination pack (2) defining a longitudinal axis (Z), said stator lamination pack being substantially U-shaped and having a pair of

segments (5, 5') which are substantially parallel to said longitudinal axis (Z);

at least one electric winding (6, 6') wound around said stator lamination pack;

a rotor (3) made of a material with high magnetic retentivity, said rotor having an axis of rotation which is parallel to said longitudinal axis (Z);

characterized in that said segments (5, 5') have free ends which are formed by the laminations of the stator lamination pack (2) and which substantially enclose said rotor (3), and in that the laminations of said stator (2) including said free ends of the segments (5, 5') extend in a parallel direction to the rotor axis (Z) to thereby limit a transverse dimension of the motor perpendicular to the rotor axis.

2. Synchronous electric motor according to claim 1, characterized in that said electric winding (6, 6') have turn axes (A, A') which are substantially parallel to the axis (Z) of the rotor (3).

3. Synchronous electric motor according to claim 2, characterized in that said segments (5, 5') of the stator lamination pack (2) have different heights along a direction (X) at right angles to the axis (Z) of the rotor (3).

4. Synchronous electric motor according to the preceding claims, characterized in that the lamination (4) have a recess (9) along the internal profile of the parallel segments (5, 5'), said recess being suitable to locally reduce the axial component of the magnetic flux.

5. Synchronous electric motor according to the preceding claims, characterized in that the stator pack (2) with its windings (6, 6') is embedded in a matrix (12) of insulating resin which is in turn enclosed and sealed within a substantially rigid container (11) made of dielectric material.

6. Synchronous electric motor according to claim 5, characterized in that said container (11) has, at an axial end (16), a cylindrical cavity (17) which extends between the segments (5, 5') of the pack (2) and is sized so as to freely accommodate the rotor (3), and has, at the opposite end, a substantially flat wall (14).

7. Synchronous electric motor according to one or more of claims 1 to 6, characterized in that it includes a modular stator capsule (13) which comprises a substantially rigid container (11) made of dielectric material which is provided with magnetizing windings (6, 6') and is embedded in a matrix of

insulating resin (12).

8. Submersible pump, particularly for aquariums, driven by a synchronous electric motor (1) according to claim 7, characterized in that the modular stator capsule (13) can be coupled to an interchangeable rotor unit (20) of a different kind.
9. Submersible pump according to claim 8, characterized in that said interchangeable rotor unit (20) comprises an elongated shell (21) which has, toward one end, a pressure chamber (23) which is suitable to accommodate an impeller (26) and is connected to an intake duct (24) and to a delivery duct (25), and has, at the opposite end, an opening (22) for the insertion of said modular stator capsule (13).
10. Submersible pump according to claim 9, characterized in that the delivery duct (25) of said shell (21) extends axially toward the insertion opening (22) of the stator capsule (13), so as to form a centrifugal pump with reversed axial flow.
11. Submersible pump according to claim 9, characterized in that the delivery duct (25) extends axially in the opposite direction with respect to the insertion opening (22) of the stator capsule (13), so as to form a centrifugal pump with direct axial flow.
12. Submersible pump according to claim 9, characterized in that the delivery duct (25) is directed substantially radially, so as to form a centrifugal pump with radial flow.

#### Patentansprüche

1. Elektrischer Synchronmotor, insbesondere für Tauchpumpen mit

- einem Ständerblechpaket (2), welches eine Längsachse (Z) definiert, wobei das Ständerblechpaket im wesentlichen U-förmig ist und ein Paar von Segmenten (5, 5') aufweist, welche im wesentlichen parallel zur Längsachse (Z) verlaufen;
- wenigstens einer elektrischen Wicklung (6, 6'), die um das Ständerblechpaket gewickelt ist; und
- einem Rotor (3) aus einem Material mit hoher magnetischer Remanenz, wobei der Rotor eine Rotationsachse aufweist, welche parallel zur Längsachse (Z) verläuft;

dadurch gekennzeichnet, daß die Segmente (5, 5') freie Enden aufweisen, die durch die Schichten des Ständerblechpakets (2) geformt sind und im wesentlichen den Rotor (3) einschließen, und daß die

Schichten des Ständers (2) mit den freien Enden der Segmente (5, 5') in einer Parallelrichtung zur Rotorachse (Z) verlaufen und somit eine Querdimension des Motors rechtwinklig zur Rotorachse begrenzen.

2. Elektrischer Synchronmotor nach Anspruch 1, dadurch gekennzeichnet, daß die elektrische Wicklung (6, 6') Wicklungsachsen (A, A') aufweisen, welche im wesentlichen parallel zur Achse (Z) des Rotors (3) verlaufen.
3. Elektrischer Synchronmotor nach Anspruch 2, dadurch gekennzeichnet, daß die Segmente (5, 5') des Ständerblechpakets (2) in einer Richtung (X) in rechtem Winkel zur Achse (Z) des Rotors (3) unterschiedliche Höhen haben.
4. Elektrischer Synchronmotor nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die Schichten (4) einen Einschnitt (9) entlang der inneren Profile der parallelen Segmente (5, 5') aufweisen, wobei der Einschnitt geeignet ist um örtlich die axiale Komponente des magnetischen Flusses zu reduzieren.
5. Elektrischer Synchronmotor nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß das Ständerpaket (2) mit seinen Wicklungen (6, 6') in eine Matrix (12) aus Isolationsharz eingebettet ist, welche ihrerseits in einen im wesentlichen steifen Behälter (11) aus einem dielektrischen Material eingeschlossen und versiegelt ist.
6. Elektrischer Synchronmotor nach Anspruch 5, dadurch gekennzeichnet, daß der Behälter (11) an einem axialen Ende (16) eine zylindrische Ausnehmung (17) aufweist, welche sich zwischen den Segmenten (5, 5') des Pakets (2) streckt und so bemessen ist, um den Rotor (3) frei aufzunehmen, und an dem entgegengesetzten Ende eine im wesentlichen flache Wand (14) hat.
7. Elektrischer Synchronmotor nach wenigstens einem der Ansprüche 1 bis 6, dadurch gekennzeichnet, daß dieser eine Modul-Ständer-Kapsel (13) umfaßt, welche einen im wesentlichen steifen Behälter (11) aus einem dielektrischen Material aufweist, welcher Magnetisierungswicklungen (6, 6') umfaßt und in eine Matrix aus Isolierharz (12) eingebettet ist.
8. Tauchpumpe, insbesondere für Aquarien, angetrieben durch einen elektrischen Synchronmotor (1) nach Anspruch 7, dadurch gekennzeichnet, daß die Modul-Ständer-Kapsel (13) mit einer auswechselbaren Rotoreinheit (20) unterschiedlicher Art gekoppelt werden kann.

9. Tauchpumpe nach Anspruch 8, dadurch gekennzeichnet, daß die auswechselbare Rotoreinheit (20) eine längliche Schale (21) aufweist, welche an einem Ende eine Druckkammer (23) hat, die geeignet ist, ein Gebläserad (26) aufzunehmen, und an einen Ansaugkanal (24) und einen Auslaßkanal (25) angeschlossen ist und an dem entgegengesetzten Ende eine Öffnung (22) für den Einsatz der Modul-Ständer-Kapsel (13) hat.
10. Tauchpumpe nach Anspruch 9, dadurch gekennzeichnet, daß der Auslaßkanal (25) der Schale (21) sich axial zu einer Einsetzöffnung (22) der Ständer-Kapsel (13) erstreckt, um so eine Zentrifugalpumpe mit umgekehrten Axialfluß zu bilden.
11. Tauchpumpe nach Anspruch 9, dadurch gekennzeichnet, daß der Auslaßkanal (25') sich axial in der entgegengesetzten Richtung im Hinblick auf die Einsetzöffnung (22) der Ständer-Kapsel (13) erstreckt, um so eine Zentrifugalpumpe mit direktem Axialfluß zu bilden.
12. Tauchpumpe nach Anspruch 9, dadurch gekennzeichnet, daß der Auslaßkanal (25'') im wesentlichen radial gerichtet ist, um so eine Zentrifugalpumpe mit Radialfluß zu bilden.

#### Revendications

1. Moteur électrique synchrone, en particulier pour pompes submersibles, comportant :

un paquet de tôles de stator (2) définissant un axe longitudinal (Z), ledit paquet de tôles de stator ayant à peu près une forme de U et ayant deux segments (5, 5') qui sont à peu près parallèles audit axe longitudinal (Z) ;  
au moins un enroulement électrique (6, 6') enroulé autour dudit paquet de tôles de stator ;  
un rotor (3) constitué d'un matériau ayant une aimantation magnétique rémanente élevée, ledit rotor ayant un axe de rotation qui est parallèle audit axe longitudinal (Z) ;

caractérisé en ce que lesdits segments (5, 5') ont des extrémités libres qui sont formées par les tôles du paquet de tôles de stator (2) et qui enferment à peu près ledit rotor (3), et en ce que les tôles dudit stator (2) constituant lesdites extrémités libres des segments (5, 5') s'étendent dans une direction parallèle à l'axe du rotor (Z) pour limiter ainsi la dimension transversale du moteur perpendiculaire à l'axe du rotor.

2. Moteur électrique synchrone selon la revendication 1, caractérisé en ce que lesdits enroulements élec-

triques (6, 6') ont des axes de spire (A, A') qui sont à peu près parallèles à l'axe (Z) du rotor (3).

3. Moteur électrique synchrone selon la revendication 2, caractérisé en ce que lesdits segments (5, 5') du paquet de tôles de stator (2) ont des hauteurs différentes dans une direction (X) à angle droit par rapport à l'axe (Z) du rotor (3).

4. Moteur électrique synchrone selon les revendications précédentes, caractérisé en ce que les tôles (4) ont une cavité (9) le long du profil intérieur des segments parallèles (5, 5'), ladite cavité étant adaptée pour réduire localement la composante axiale du flux magnétique.

5. Moteur électrique synchrone selon l'une quelconque des revendications précédentes, caractérisé en ce que le paquet de stator (2), muni de ses enroulements (6, 6'), est enrobé dans une matrice (12) constituée de résine isolante qui est à son tour enfermée et rendue étanche dans un container pratiquement rigide (11) constitué d'un matériau diélectrique.

6. Moteur électrique synchrone selon la revendication 5, caractérisé en ce que ledit container (11) a, au niveau d'une extrémité axiale (16), une cavité cylindrique (17) qui s'étend entre les segments (5, 5') du paquet (2) et dimensionnée de manière à recevoir librement le rotor (3) et a, au niveau de l'extrémité opposée, une paroi à peu près plate (14).

7. Moteur électrique synchrone selon l'une quelconque des revendications 1 à 6, caractérisé en ce qu'il comporte une capsule de stator modulaire (13) qui comporte un container à peu près rigide (11) constitué d'un matériau diélectrique qui est muni d'enroulements magnétisant (6, 6') et qui est enrobé dans une matrice constituée d'une résine isolante (12).

8. Pompe submersible, en particulier pour des aquariums, entraînée par un moteur électrique synchrone (1) selon la revendication 7, caractérisée en ce que la capsule de stator modulaire (13) peut être reliée à un ensemble de rotor interchangeable (20) d'un type différent.

9. Pompe submersible selon la revendication 8, caractérisée en ce que ledit ensemble de rotor interchangeable (20) comporte une enveloppe allongée (21) qui a, vers une première extrémité, une chambre de pression (23) qui est adaptée pour recevoir une hélice (26) et est reliée à un conduit d'admission (24) et à un conduit de refoulement (25), et a, au niveau de l'extrémité opposée, une ouverture (22) destinée à l'insertion de ladite capsule de stator mo-

dulaire (13).

10. Pompe submersible selon la revendication 9, caractérisée en ce que le conduit de refoulement (25) de ladite enveloppe (21) s'étend axialement vers l'ouverture d'insertion (22) de la capsule de stator (13), de manière à former une pompe centrifuge ayant un écoulement axial inversé. 5
11. Pompe submersible selon la revendication 9, caractérisée en ce que le conduit de refoulement (25') s'étend axialement dans la direction opposée par rapport à l'ouverture d'insertion (22) de la capsule de stator (13), de manière à former une pompe centrifuge ayant un écoulement axial direct. 10 15
12. Pompe submersible selon la revendication 9, caractérisée en ce que le conduit de refoulement (25'') est dirigé à peu près radialement, de manière à former une pompe centrifuge ayant un écoulement radial. 20

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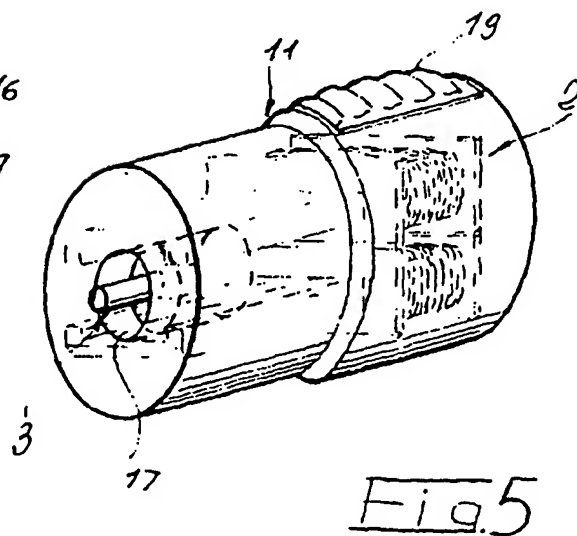
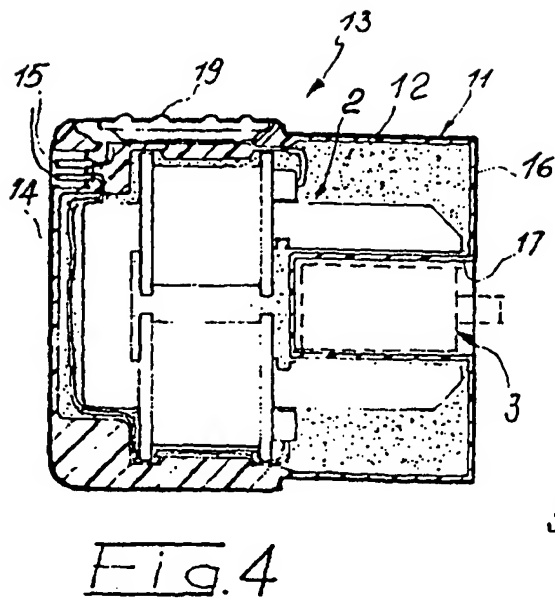
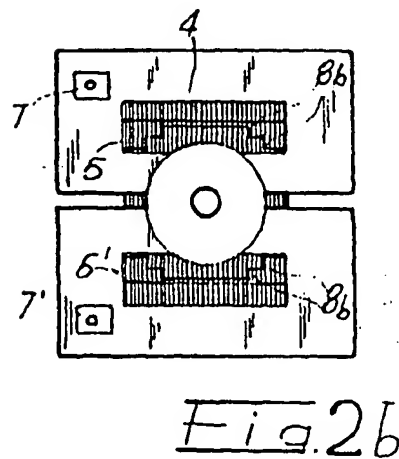
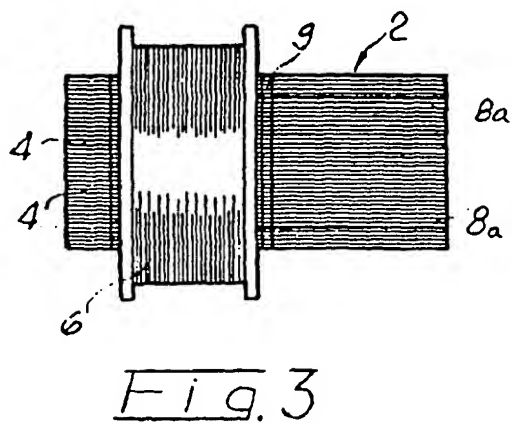
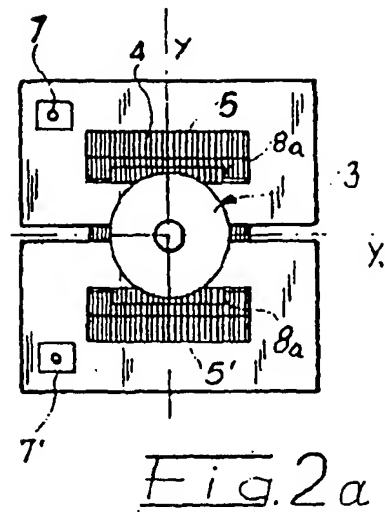
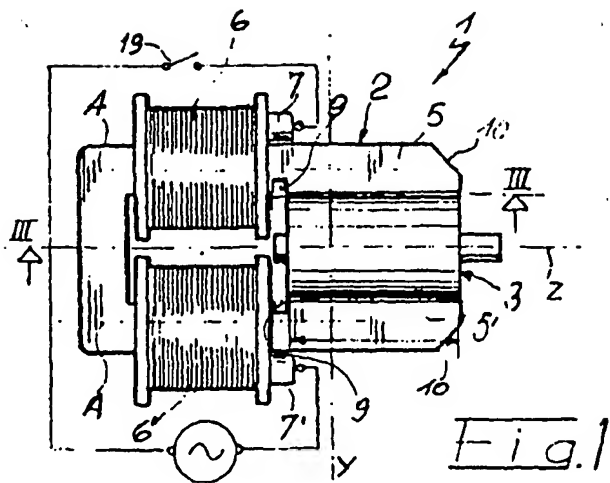




Fig. 6

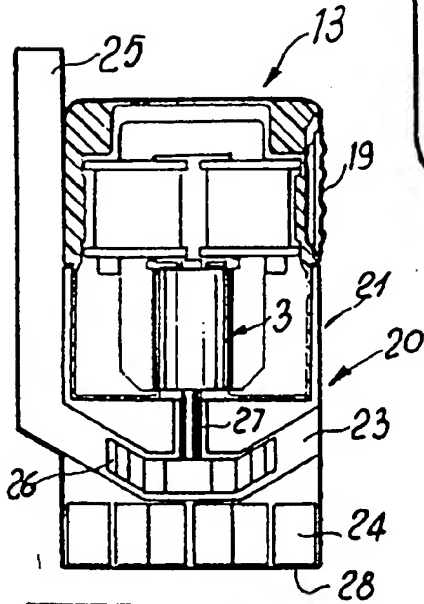
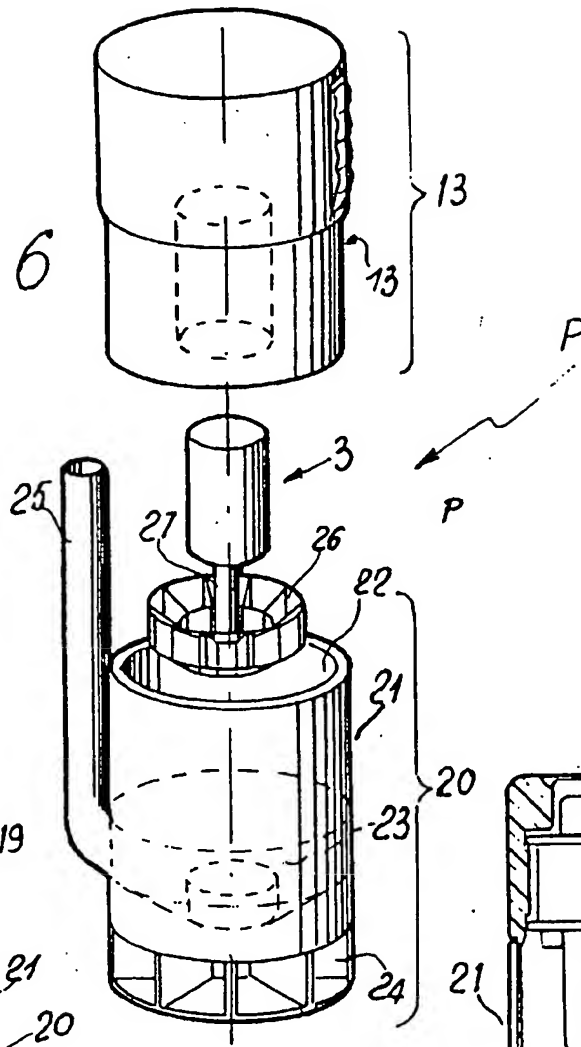


Fig. 7

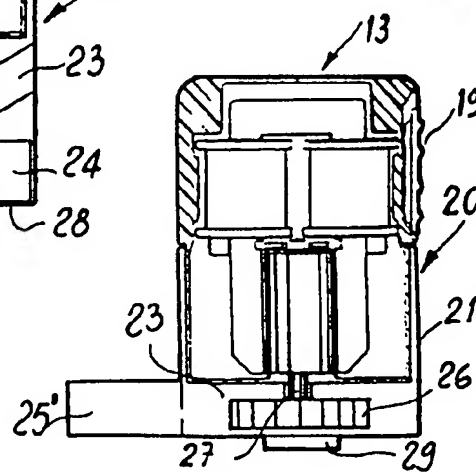


Fig. 9

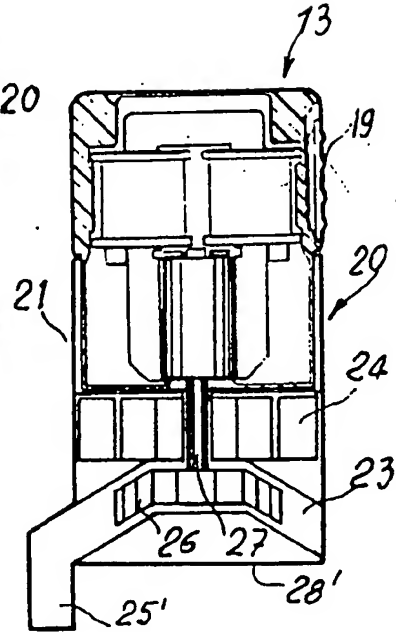


Fig. 8